T4.1-P12

Improving detection quality of primary IMS seismic stations

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CTBTO PREPARATORY COMMISSION

Abstract

Monitoring of underground nuclear tests is based on the Primary Seismic Network of the International Monitoring System (IMS) consisting of 3-C stations and arrays. Detection of signals is the principal task of stations. The capability of finding an event of interest depends on station sensitivity, i.e. detection threshold and reliability of signal attributes such as arrival time, signal-to-noise ratio, amplitude, period, and so on. The current set of parameters used by the International Data Centre for station processing yields a detection list of good quality. There are several problems, however, that call for further improvement. These include, *inter alia*, a high rate of phases wrongly associated with event hypotheses during automatic processing, a large fraction of manually added arrivals (more than 10%), arrivals renamed from noise (N-) phases (up to 10%) in the Reviewed Event Bulletin, and retiming of many arrivals by more than 4 s. To investigate the reasons for these and other problems and to find appropriate solutions, the IDC develops a tool for off-line data re-processing and analysis. We present its methods of analysis and parameter optimization.

STATION TUNING FRAMEWORK

The IDC operational environment (OPS) for SHI processing is a complex collection of configuration, database, and software resources. Station tuning requires offline processing in an environment that mirrors OPS so that optimization results are representative of and applicable to OPS. Moreover, access to archival data is imperative since long periods of historical data are to be reprocessed to gather significant tuning statistics.

A Python framework for station tuning has been developed. On starting a station tuning job, the framework executes the following preparatory steps to set up an OPS-equivalent processing environment:

Configuration copying

- A symlinks copy of the 8GB SHI config tree of the OPS filesystem is made.
- Those config files that need adjustment, e.g. files holding the parameters to be tuned, are copied and patched instead of symlinked.
- Uniquely-named transient folders in /tmp are used to allow parallel job runs.

Database initialization

- Two dedicated database accounts in an archival database are used:
  - ➢ A *tables account* where input tables with adjusted content or output tables are set up. Indices, constraints and content are copied from the source tables without requiring database links or access to schema DDL.
  - ➢ An *accessor account* holding synonyms to tables in the archival database and the tables account. The accessor account provides the equivalent of a processing account to the pipeline stages to be run.
- The account pair is first emptied to start with a clean slate.
- Multiple account pairs are used for parallel job runs.
- Since archival databases do not provide all tables present in the operational databases, missing tables are copied from operational databases as required.

Software environment setup

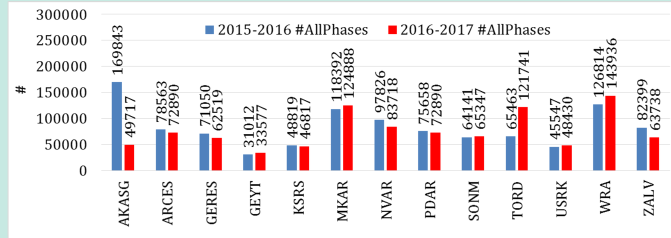
- Environment and imspar variables are set to make the OPS LAN scripts and binaries available.
- Job-support support libraries and scripts are put on-(PYTHON)PATH.
- Binaries can be overridden with custom-compiled versions, e.g. to make debug symbols available to a debug session.

Job-specific configuration, stage running, and analysis is done through concise Python3 scripts run in a virtualenv provisioned with data access and science libraries (numpy, cx_Oracle, matplotlib, and so on).

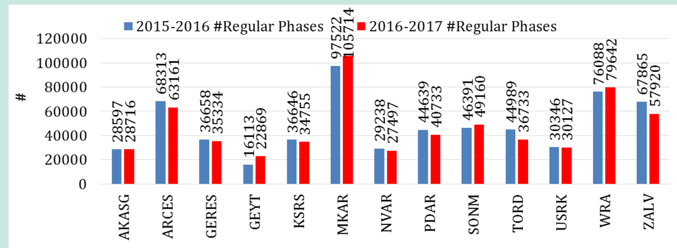
The steps for optimizing the STA/LTA detection thresholds (IDC 5.2.1)

1. Run the *DFX* application using a STA/LTA threshold of 3.0 for all channels on **"control"**[1] data that have been reviewed by analysts.
2. Determine the relationships between the number and SNR of detections for each channel.
3. Determine the relationships between the number and SNR of associated phases for each channel.
4. Determine the relationships between the number and SNR of added (missed) phases for each channel.
5. Set an objective for the association rate for all channels (for example, the value currently used is 10%).
6. If the existing STA/LTA threshold for channels with the same slowness and frequency band has an association rate that is lower than the objective, increase the thresholds of the channels to a value for which the objective is achieved.
If the existing STA/LTA threshold for channels with the same slowness and frequency band has an association rate that is higher than the objective, decrease the thresholds of the channels to a value for which the objective is achieved (or the percentage of added phases becomes zero).
7. Repeat steps 4 and 5 until a relationship between the association rate and the added rate is obtained.
8. Choose a point where the added rate is lower than a given percentage of the total associated rate, say 20% (first priority) and the association rate is a set percentage of the detection rate, say 10%, (second priority).
9. Test the modified recipe by running the *DFX* application.

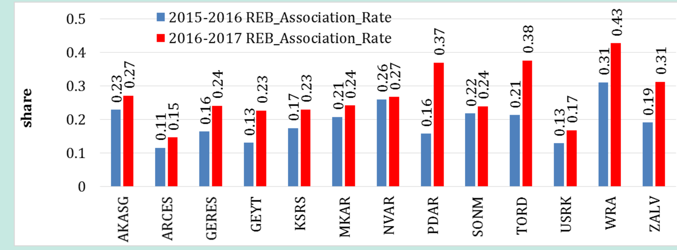
TIME VARIATION



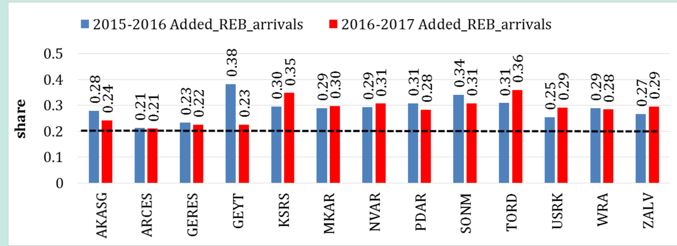
The number of phases in the IDCX arrival table for primary IMS stations as observed during two previous 365-day-long periods.



The number of regular phases in the IDCX arrival table for primary IMS stations as observed during two previous 365-day-long periods.

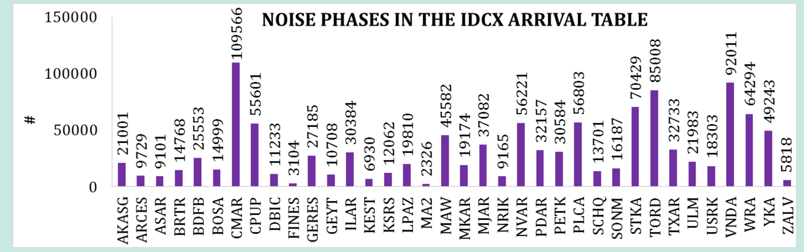


The share of IDCX phases associated with REB events as observed during two previous 365-day-long periods.

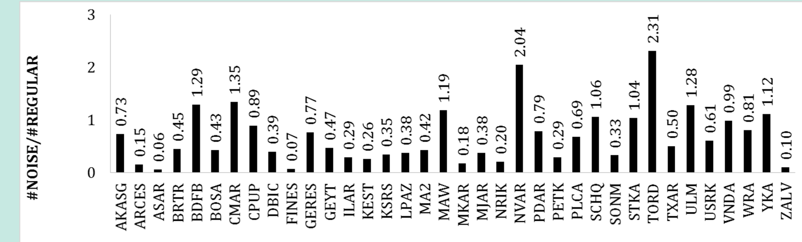


The share of manually added phases in the REB arrival table for primary IMS stations as observed during two previous 365-day-long periods.

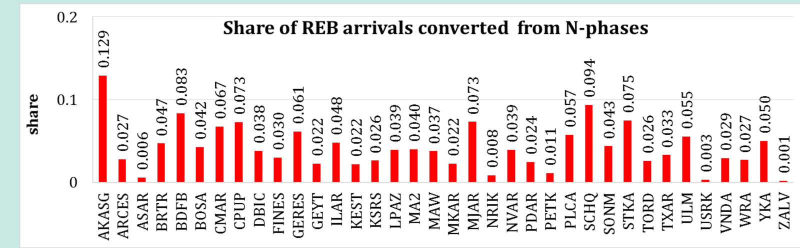
NOISE PHASES



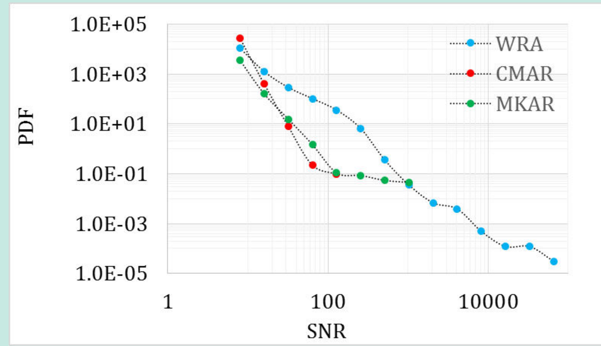
The number of noise (N-) phases in the IDCX arrival table for primary IMS stations as observed during the 365-day-long period.



The ratio of noise (N-) and regular phases in the IDCX arrival table for primary IMS stations as observed during the 365-day-long period.

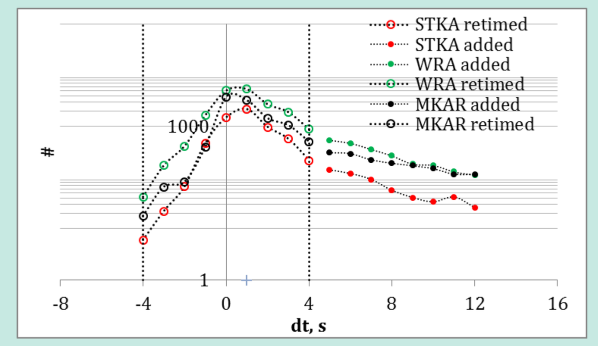


The share of noise (N-) phases in the IDCX arrival table converted into regular REB phases.

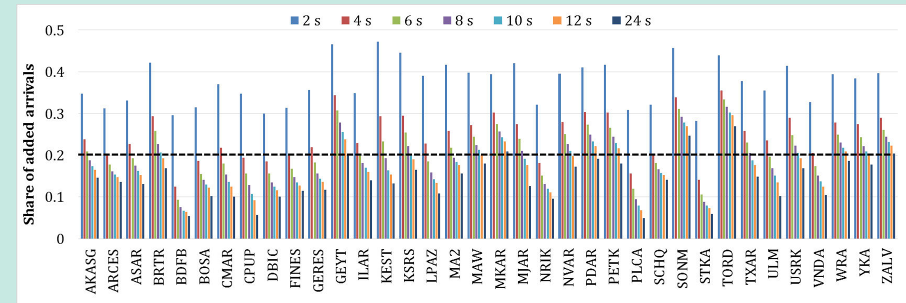


The PDF of noise phases in the IDCX arrival table as a function of SNR

ARRIVAL RETIMING



The number of REB phases with changed arrival time (retimed) as a function of time change. The IDC retiming limit is 4 s. A new phase has to be added to the REB when larger retiming is needed.

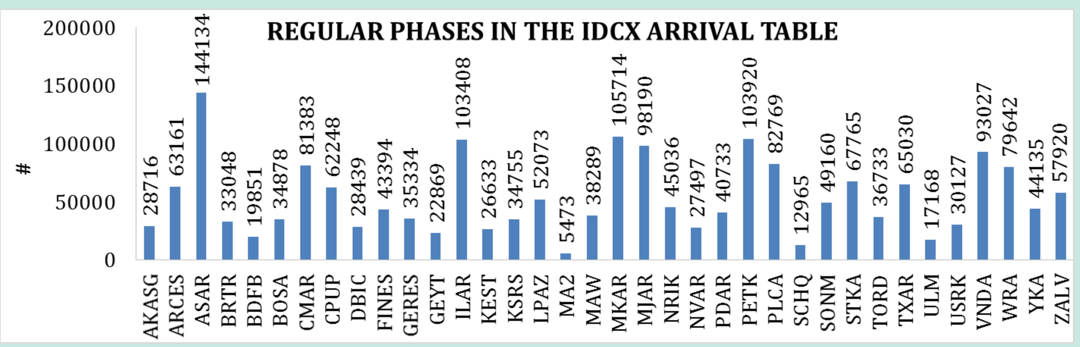


The share of IDCX arrivals associated with the REB events as a function of the allowed change in arrival time. For 10 s retiming limit, almost all stations have the rate of REB manually added arrivals below 20%.

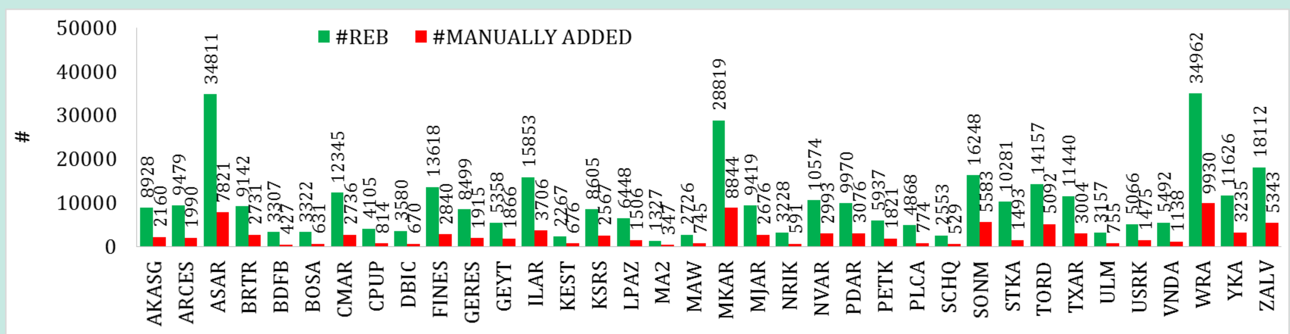
Figure above presents the change in the share of manually added arrivals for different allowed retiming limits. We use regular and noise phases from the IDCX *arrival* table and arrivals in the REB *assoc* table. The interval of 4 s is identical to the case of *arid* comparison. For a 2 s limit, one can observed a dramatic increase in the share of manually added phases – all stations have the rate far above 20%. This rate rapidly falls with increasing limit and for 10 s all stations of interest, except TORD, have the rate of manually added arrivals below or very close to 20%. The added arrivals, which are close (say, less than 12 s) to their parent arrivals, are not a big problem for analysts and do not need much extra time compared to pure retiming.

Many signals detected by IMS seismic stations are of emergent character, with signal amplitude growing slowly to its maximum. In this situation, the IDC detection threshold may be reached in ten and more seconds after actual arrival time. Automatic processing is not able to find signals below the predefined STA/LTA ratio. IDC analysts can add an arrival where it has to be with lower SNR and at self-designed detection channels.

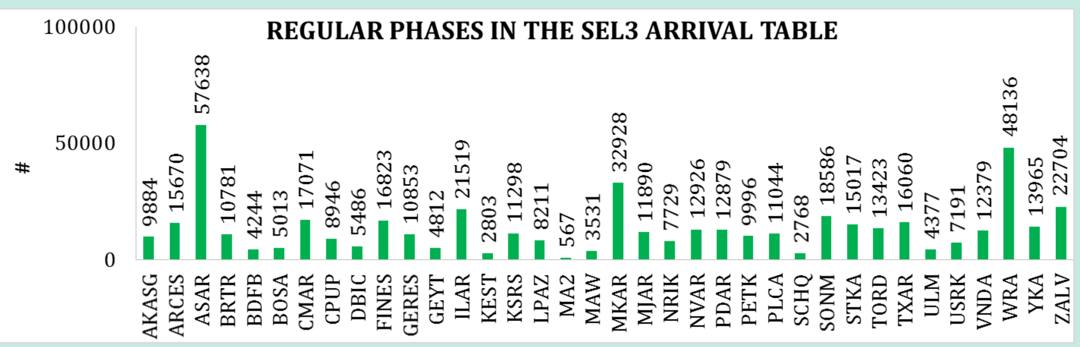
ASSOCIATED AND MANUALLY ADDED ARRIVALS



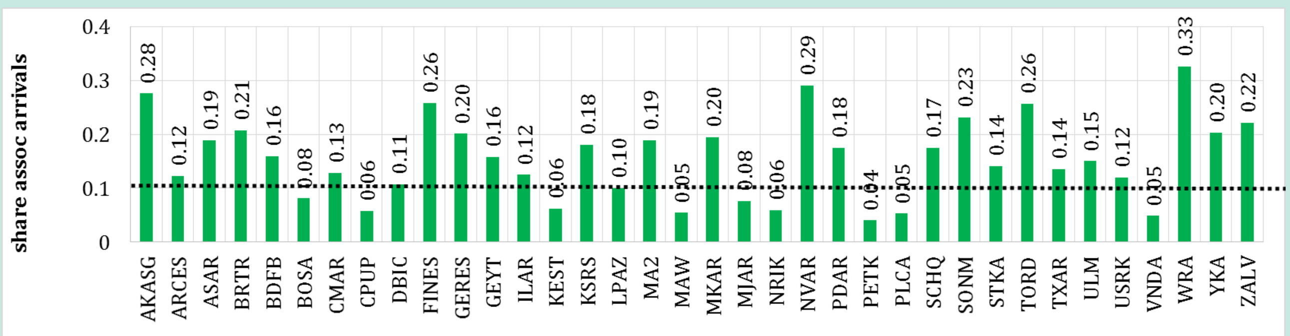
The number of regular phases in the IDCX arrival table (detection list) for primary IMS stations for last 365 days.



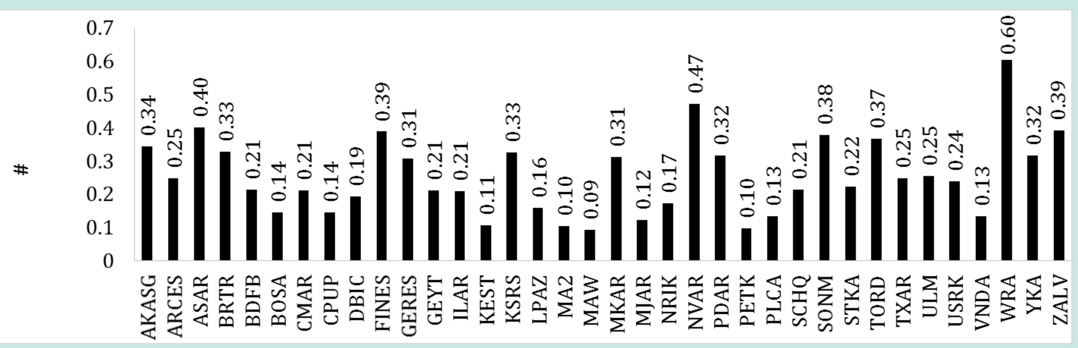
The number of regular phases in the REB arrival table for primary IMS stations for last 365 days.



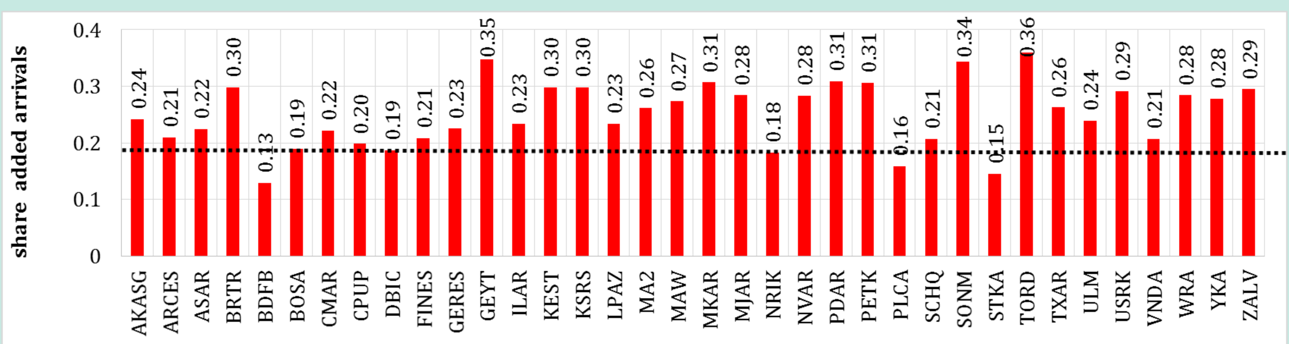
The number of regular phases in the SEL3 (automatic bulletin) arrival table for primary IMS stations for last 365 days.



The share of regular phases in the IDCX arrival table associated with REB events for primary IMS stations for last 365 days.

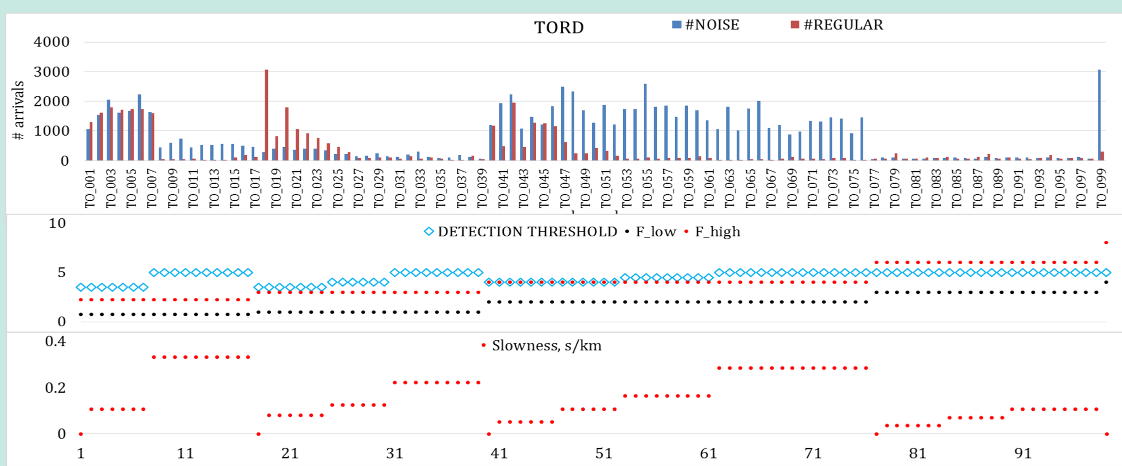


The ratio of the number of regular phases in the SEL3 (automatic bulletin) arrival table for primary IMS stations for last 365 days.

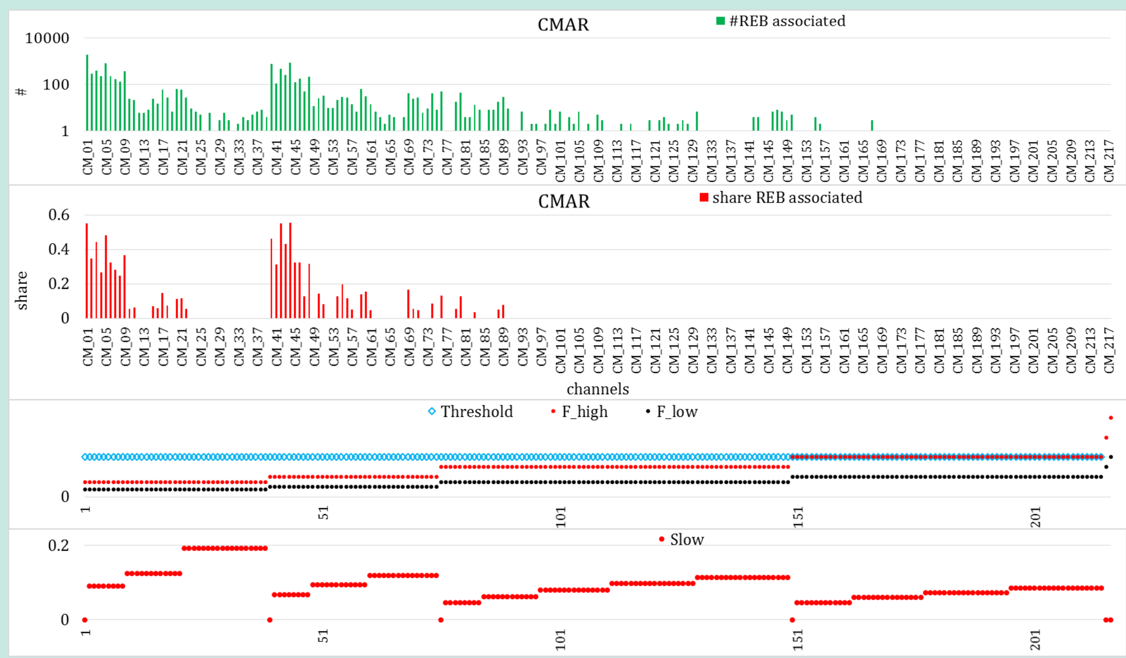


The share of manually added REB arrivals for primary IMS stations for last 365 days.

DETECTION CHANNELS

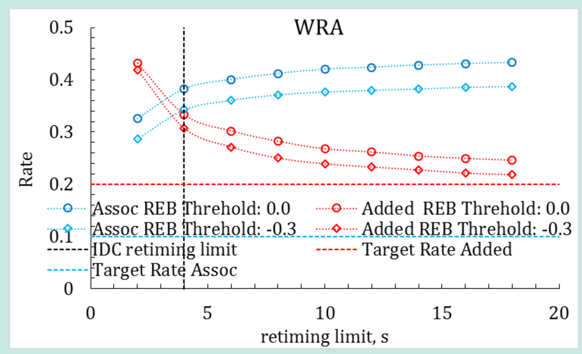


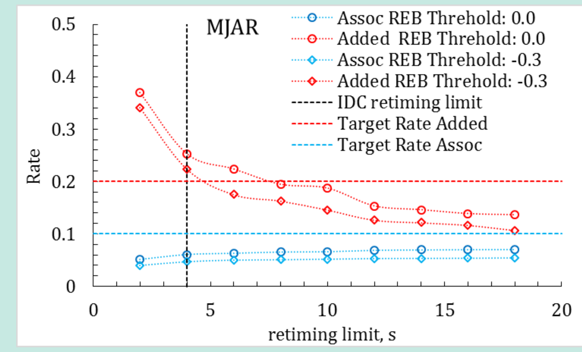
The number of regular and noise IDCX arrivals associated at each of 99 detection channels of station TORD. Detection threshold, slowness and frequency band for each channel are also presented.



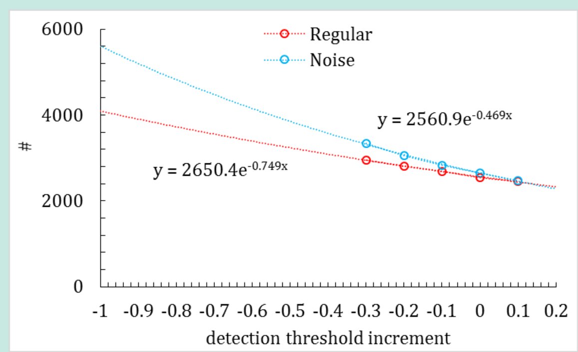
The number and share of regular IDCX arrivals associated with REB events at each of 217 detection channels of station CMAR. Detection threshold, slowness and frequency band for each channel are also presented.

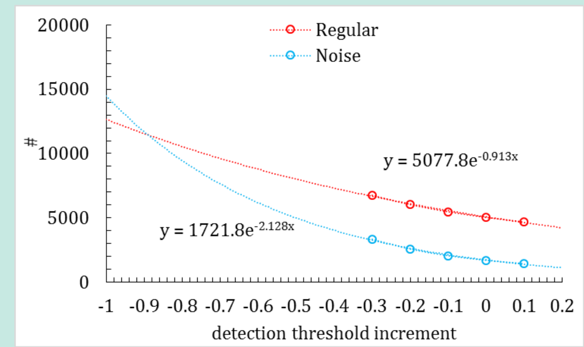
OPTIMIZING DETECTION THRESHOLD



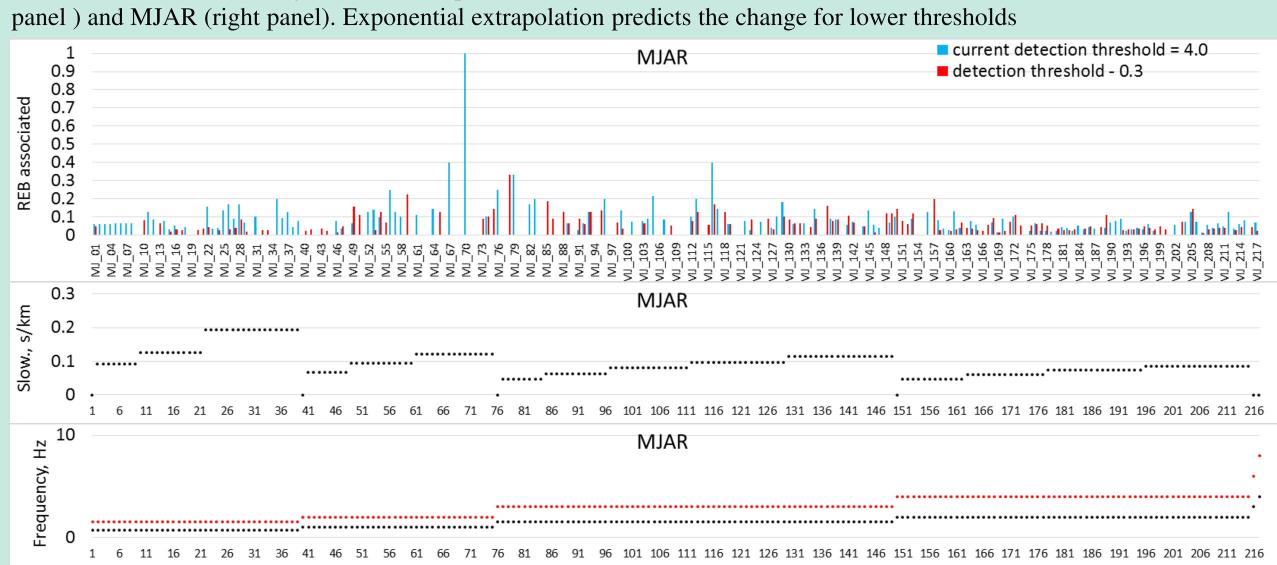


The share of IDCX arrivals associated with the REB events and manually added REB arrivals as a function of detection threshold and the allowed change in arrival time at stations WRA (left panel) and MJAR (right panel)





Growth in the number of regular and noise phases as a function of the decrease in detection threshold at stations WRA (left panel) and MJAR (right panel). Exponential extrapolation predicts the change for lower thresholds



The change in the share of IDCX arrivals associated with REB events as a function of the decrease in detection threshold at each detection channel of station MJAR. Slowness and frequency band for each channel are also presented.

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